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ANALYSIS OF PRODUCT QUALITY IMPROVEMENT ELECTRICAL COMPONENTS BASED ON THE SIX SIGMA METHOD

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ABSTRACT

The Six Sigma method is used as an effort to minimize defective products and improve product quality in a company. This research was conducted using the DMAIC step. The case study taken in this research is the electrical components and samples of the product is Bakelite busbar Holder are taken. Based on field studies conducted, this product has the highest defect rate in the company compared to other products, namely 1.448%. The purpose of this research is to identify the causes of defects in bakelite busbar holder products and to propose strategies to minimize product defects using the Six Sigma method approach. By using the DMAIC stage, in the define stage, the problematic products are determined and critical to quality diagrams are made. In the measure stage, calculations are carried out to determine the company's DPMO and sigma level, namely 3021.87 and 4.24. In the analyze phase, Pareto diagrams, fishbone diagrams, and FMEA are used. In the improve stage, the 5W + 1H method is used and provides suggestions for improvements in the form of a material storage area design and One Point Lesson. Whereas in the final stage, control is implementing using the proposals given and analyzing the results after the implementation is carried out. Based on the implementation carried out, the DPMO value was 1312.69 and the sigma value was 4.509. It can be seen that the DPMO value decreased by 56.56% and the company's sigma value increased by 5.846%.
Keywords: *Six Sigma, DMAIC, FMEA, Electrical Component, bakelite busbar holder*

1. INTRODUCTION

Product quality is a condition of an item based on an assessment of conformity with established standards. The more according to the standards set, it will be judged that the product is of higher quality. Quality is the most essential thing that must be maintained within the company to improve and maintain customer satisfaction [1,2]. Product quality is a potential strategic weapon to beat competitors. The ability of product quality to perform various functions, including durability, reliability, accuracy, and ease of use [3]. Product quality can be concluded as a reference in making products to get maximum results.

Based on the data obtained, the Bakelite Busbar Holder product has the largest number of defects totaling 1,448%. Busbar Holder is an electrical insulator on the panel; an electrical insulator is a material that cannot or is difficult to carry an electric current. Busbar Holders has its main function as a barrier or barrier to electric current to avoid electric shocks, short circuits, and avoid fire hazards caused by electrical conductors touching each other so that their quality must be maintained. Electrical isolators are generally used in electrical cables, electrical cable connections and in installing electric busbars. Busbar Holder Isolator is an electrical insulator used to install busbar circuits. This busbar isolator functions as a busbar support or separator between the busbars so that no current flows out between the busbars. The following Table 1 is data on the number of defective Busbar Holders. Figure 1 is a Product Picture of a Bakelite Busbar Holder.

Table 1. Number Of Busbar Holders Defect

Type	Group	No. of Product (pcs)	No. of Defect (pcs)	Defect Percentage (%)
Bakelite Busbar Holder	1	42.312	297	0,7
	2	75.494	1.383	1,83
	3	42.131	165	0,39
	4	24.564	18	0,07
	5	33.779	1.435	4,25
Total	-	218.280	3.298	1,510

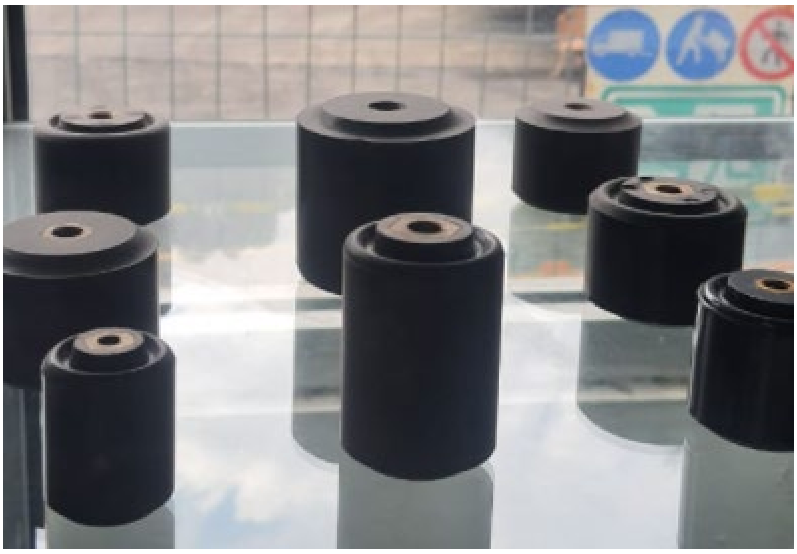

Figure 1. Bakelite Busbar Holders

Based on the existing field studies, it is necessary to have effort to find out and identify the causes of existing product defects and provide appropriate repair strategies to reduce the occurrence of product defects. The method that can help overcome this problem is the Six Sigma Method. The Six Sigma method focuses on minimizing product defects and improving product quality using the DMAIC stages.

2. RESEARCH METHODOLOGY

Stages The research methodology carried out consisted of several stages. Beginning with field studies and library studies. In the field study, observation activities were carried out and observing the conditions and problems in the field. The next step is to determine the identification of the problem, namely regarding the presence of product defects in the bakelite busbar holder components. After identifying existing problems, next is a Literature Study to choose the appropriate method related to the existing issues. Followed by selecting research objectives and collecting data. The data collected consists of primary data and secondary data. All the above stages are part of the Define stage in the Six Sigma method.

The next stage is the Measure stage. At this stage, calculations are carried out from the data to determine the DPMO value and sigma value, as well as calculating the P control chart. The next stage is the Analyze stage. At this stage several tools are used, namely Pareto Diagrams and FMEA. The next stage is the Improve Stage. The Improve stage is used to provide proposals for improving designs from existing problems and identify using 5W + 1H, provide suggestions for improvements in the form of design tools. The final stage is the Control stage. Control is used to control the design of improvements, as well as implementing proposals with new calculations of improvements to see the impact of the improvements made. After completion, conclusions are drawn from the results of this study.

Six Sigma

Six Sigma is a business method that aims to increase competency values from various business process activities [4]. Basically, Six Sigma identifies defects and minimizes defects that occur in products, by measuring defects so that defects can be eliminated. The goal is to get zero defects. The aspects that must be considered when six sigma is applied in the manufacturing industry are as follows [5]:

a. Identification of product characteristics that satisfy customers (according to customer needs and expectations).
b. Classify all the quality characteristics as individual CTQ (critical to quality).
c. Determine whether each CTQ can be controlled through control of materials, machines, work processes, and others.
d. Determine the maximum tolerance limit for each CTQ according to what the customer wants (determine the UCL and LCL values of each CTQ).
e. Determine the maximum process variation for each CTQ (determine the maximum standard deviation value for each CTQ).
f. Changing the product and or process design in such a way as to be able to achieve the six-sigma target value.

DMAIC Phase

DMAIC is a phase concept consisting of [6]: The Define phase is the initial stage of the DMAIC process, the define phase is the stage that explains the problem that is occurring and provides an explanation of the purpose of the case study. The Measure stage is the second stage in DMAIC, the measure stage is the stage of measuring existing problems. This stage collects data to solve existing problems. The Analyze stage is the stage of analyzing existing problems and looking for root causes and solutions to solve problems. After the analyze phase is complete, get the root of the problem and the solution. The next stage is the Improve stage, at this stage testing is carried out for existing solutions so that these solutions are valid and useful for the problems that are happening. The last stage is the control stage, the control stage functions to control, maintain, and improve the solutions provided so that solutions can be long term and prevent potential problems that will occur in the future or when there is a change in process, workforce, or management change.

Critical To Quality (CTQ)

Critical To Quality (CTQ), are very important attributes to pay attention to because they are directly related to customer needs and satisfaction. CTQ is an element of a product, process, or practices that has a direct impact on customer satisfaction [7]. CTQ is a tool used to measure a product or process to achieve standard performance or limits of its specifications to satisfy the wants and needs of customers. CTQ. CTQ Tree (Critical to Quality tree) is used to describe or decompose broad customer requirements into quantified requirements and process them more easily.

Failure Mode Effect Analysis (FMEA)

FMEA is a technical analysis which, if done properly and at the right time, will provide great value in assisting the decision-making process of the engineer during design and development. This analysis is usually called a "bottom up" analysis, such as checking the initial production process and considering system failures which are the result of all different failure forms [8]. The purpose of FMEA is to find problems that occur in production and provide recommendations for system improvements. There are four steps in the performance of the FMEA as follows:
a. Defining the system, its functions, and components.
b. Identify the causes of the problems that arise.
c. Studying existing problems that cause component defects.
d. Conclusions and recommendations.
In the FMEA method, to see priority risk severity or RPN, you must look for the value of Severity, Occurrence, & Detection.

Defect Per Million Opportunities (DPMO) And Sigma Level

Defect per million opportunities (DPMO) is a measure of work performance, where the measurement measures 1 million items. The formulas in DPMO are [9]:

$$\text{DPMO} = \frac{\text{Number of Defect}}{\text{Unit x Defect Opportunity}} \text{ x } 1.000.000$$

The sigma value is a measure that states the magnitude of a process capability, the higher the sigma value obtained the greater the existing process capability. The sigma value is high because there is very little variation in the process or very few defects. The formula for calculating the Sigma Level using the help of a formula in Microsoft Excel is:

$$= NORMSINV\left(\frac{1.000.000 - DPMO}{1.000.000}\right) + 1{,}5$$

P-Chart

Control-p chart to see whether the quality control of a product is under control or not. The p control chart can show information where the company must make improvements and assist in quality control [10].

3. RESULTS AND DISCUSSIONS

Define Phase

The define phase is used to identify problems or manage existing data on products and see problems that exist with consumers to improve the production process [11]. Product selection is done by looking at the highest level of product defects from the products produced by the company.

After observing and collecting data, the busbar holder product has the highest percentage, namely 1.448%. Figure 2 is a CTQ Tree (Critical to Quality tree) used to describe or decompose broad customer requirements into quantified requirements and process them more easily.

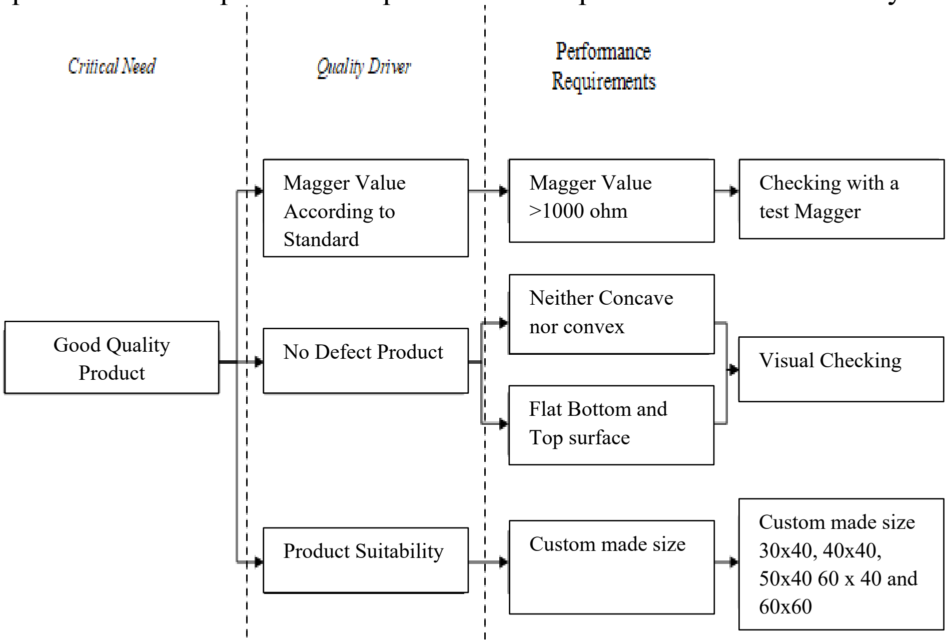

Figure 2. Critical To Quality Tree

Measure Phase

In the Measure Phase a p-control chart is calculated to see whether the quality control of this product is under control or not. The results obtained on the P-control chart in this busbar holder product are still outside the existing upper and lower control limits. This shows that the control of the busbar holder product is still not good and not optimal, so a quality improvement strategy is needed. Furthermore, it is included in the calculation of the DPMO value to measure process capability. The following is a DPMO calculation. Obtained DPMO results of 3021.87, then look for the sigma level. From the results obtained it is known that the sigma level is at level 4, which means it is still not optimal and still needs to be improved in order to achieve six sigma.

$$\text{DPMO} = \frac{3298}{(218{,}280) \times 5} \text{ X } 1.000.000 = 3021{,}87$$

$$\text{Sigma Level} = \text{NORMSINV}\ (1.000.000 - 3.021{,}87/1.000.000) + 1{,}5$$
$$\text{Sigma Level} = 4{,}2454$$

Analyze Phase

The Analyze stage is used to analyze the root causes found in the measure. This stage is carried out to find the type of defect that occurs and the cause of the defect in the busbar product. The Analyze phase uses a pareto diagram to see defects, fishbone diagrams, and FMEA [12]. The following is Table 2 of the types of waste defects that occur in busbar holder products and Figure 3 Pareto diagrams of the types of waste defects of busbar holders. From Figure 3 the megger value of the product not according to the standard is the most defect at 92%, the two nozzles are damaged by 3.6% and the three product visuals are 3.2%. After knowing the 3 types of defects that are the highest, an FMEA analysis is made as can be seen in Table 3 to find out the causes of failure and the potential caused by failures so that the highest RPN value can be obtained so that the right repair plan can be identified.

Based on Table 3, the largest RPN results are obtained which are a priority in making improvements, namely the Megger value of the product does not comply with the standard with a value of 392; Napple damaged at 150; Product visuals with a rating of 144.

Table 2. Type of Defect Busbar Holder Product

Type Of Defect	Total	Percentage (%)	Cumulative (%)
No Napple on the product (1)	17	0,52	0,52
Broken Busbar (2)	6	0,18	0,7
Broken Napple (3)	122	3,70	4,4
Visual Product (4)	107	3,25	7,65
The product megger value is not in accordance with the standard (5)	3046	92,35	100
Total	3298	100	

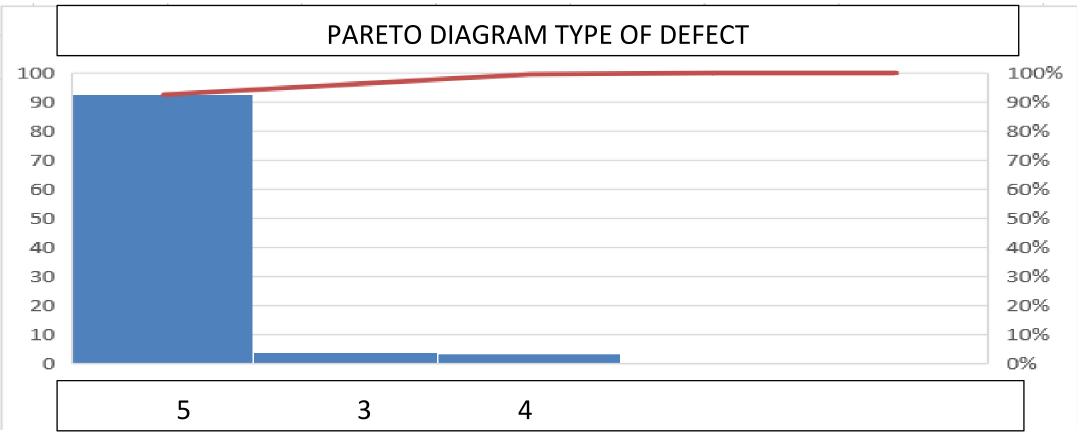

Figure 3. Pareto Diagram Type of Defect *Busbar Holder*

Improve Phase

The Improve stage, the Improve stage is used to provide suggestions for improvement designs from the root causes and identify 5W + 1H. Table 4 is the 5W + 1H table, this table functions to analyze waste which is the root cause of an existing problem and provides improvements or suggestions [13].

Table 3. FMEA Analysis

No.	Potential Failure Mode	Product Effect of Failure	S	Potential Cause	O	Current Process Control	D	RPN	Rank	Action Recommended

1	There is no napple on the product	Napple left behind or separated from the product when injecting.	5	Machine setting errors and careless operators.	4	Periodic checks are carried out on each process.	4	89	4	Conduct training for operators and review process operating procedures.
2	Broken Busbars holder	Broken or split into two during the process of re-tabling the bolt holes which are covered with material and the product becomes imperfect.	5	Error on screw tab due to operator carelessness.	3	Visual checks carried out by the operator on each production result	3	45	5	Conduct training for operators and review process operating procedures.
3	Broken Napple	Material collisions and inappropriate points during the inject napple process.	6	Error in machine and operator settings when placing the napple.	5	Visual checks carried out by the operator on each production result.	5	150	2	Conduct training and inspection of napple installation for operators on a regular basis and make a one point review.
4	Product Visuals	The product is damaged to be convex or concave.	6	Lack of material during the injection process at the beginning of the process and the injection machine is too hot.	6	Visual checks carried out by the operator on each injection process result.	4	144	3	Conduct training for operators and create a one point lesson.
5	The product's Magger value is not up to standard	The megger value is below standard.	7	There is an influence on the material because there is humidity in the air.	7	Quality control inspection of the megger value or insulation resistance is carried out on each production product.	8	392	1	Make suggestions for airtight storage containers in the busbar holder material storage areas

Table 4. 5W + 1H

No.	What	When	Where	Who	Why	How

1	Defect Product	Production process	Busbar Holder Production	Head of production	Product Megger value does not match	Problem Raw Materials	Raw materials are not dry	The quality of raw materials is not up to standard	Make a proposal for the design of an airtight storage container for busbar holder material
					Broken napple	Napple is not centre	Napple collided with the matrix	Careless operator	Conduct routine training and inspection of napple installation for operators as well as making one point review
					Product visual	Incorrect Material Measurement	The injection engine is too hot	Operators who are less thorough in the initial inspection	Conducting training for operators and making one point lesson
					Broken busbar	Broken or split into two during the process of re-tabling the bolt holes which are covered with material and the product becomes imperfect	Operator error on bolt tab	Careless operator	Conduct training for operators and review process operating procedures
					There is no Napple on the product	Napple lags behind	Napple detached at the time of injection	Careless operator	Conduct training for operators and review process operating procedures

Quality Improvement Suggestion

Based on the analysis that has been done, several suggestions can be given to improve product quality, namely:

1. Make a Material Storage Container. This is proposed because the cause of the highest defect is the product megger value that is not suitable, this is due to the humidity in the air which causes the product material not to be dry. This affects the material quality of the busbar holder product, namely pynolic must maintain dryness in the material to maintain material quality. It can also be seen that the product material is the most influential in the defects that occur. The product material storage area is currently left in the open with sacks as storage media.
2. Make a One Point Lesson. This is proposed to overcome the problem of broken napples and product visuals. This One Point Lesson aims to remind operators and increase knowledge, reminding operators that are packaged in a virtual point document. This happened because of the operator's inaccuracy in installing the napple not in the middle and the collision of the napple with the matrix and giving the operator an appropriate visual example and production defects.

Control Phase

After implementation, a re-calculation of defective products is carried out to see if there is an improvement in the existing production process. It can be seen in Figure 4, namely the P-control Map Image that exists on this busbar holder product that has entered the existing upper and lower control limits. This shows that the control of this bassholder product is good and has experienced improvement after the implementation of the proposal on the busbar holder product. DPMO and sigma level calculations were also performed after repairs were made. Based on the DPMO calculation and the new sigma level, a comparison is obtained with before the repair. Table 5 is a comparison of DPMO and sigma levels before and after.

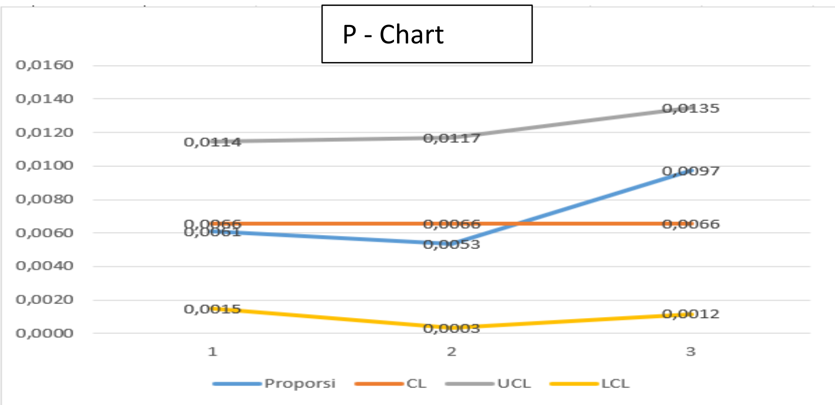

Figure 4. P-Chart After Implementation

Table 5. Comparison of DPMO and Sigma Levels Before and After Repair.

Value	Before	After	Comparison
DPMO	3021,87	1312,69	decrease 56,56%
Sigma Level	4,245399	4,509	increase 5,846%

4. CONCLUSIONS AND SUGGESTIONS

The conclusion obtained through this research is that the most common defect is the megger value of the product that does not comply with the standard by 92%, the two nozzles are damaged by 3.6% and the three product visuals by 3.2%. The DPMO result was 3021.87 and the sigma level was at level 4. After repairs were made the DPMO value decreased by 56.56% to 1312.69 and the sigma value increased by 5.846% to 4.509.

The suggestion given to the company as an effort to improve the quality of Busbar Holder products is the design of a new storage container, this is because the material is the cause of all existing defects. By designing a new storage container, it is hoped that the material will remain dry and the quality is maintained, suggestions next is making a one point lesson to prevent product visual defects and damaged napple attached to the machine, and it's done.

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